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Volume I

Editor: R. Denys

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FOREWORD

The safe and economic construction and utilisation of pipelines presents an exciting challenge to the pipeline industry. This challenge demands an interplay between research, experience and pragmatism. The first "Ostend" Pipeline Conference in Ocotober 1990 addressed all these aspects of pipelines.

These proceedings contribute to the continued development of the pipeline technology. In particular, the objective of this Conference is to inform the international pipeline community on the major developments of cross-country (transmission and distribution), offshore and deep water and arctic pipelining since 1990.

This Second "Ostend" Pipeline Technology Conference includes 130 papers to be presented in 25 sessions. The papers are published in Volume I and II. Late papers are collated in a separate Volume III. The Conference is truly an international event since the papers originate from 28 countries.

The papers give up-to-date information relative to the pipeline technology (future trends and project descriptions), pipeline design (standards and special aspects), pipeline materials (ferritic, austenitic and duplex steels, and plastics), pipeline welding (consumables, processes, and weld mis-match), non-destructive testing (radiographic and ultrasonic testing, laser technology, defect assessment) and pipeline integrity (testing, corrosion, coatings, ageing of pipelines and risk assessment).

On behalf of the Organising Committee I would like to welcome you to Ostend. It is a pleasure, too, to thank all the authors and their colleagues for the valuable time they spent in preparing their manuscripts. Finally, we wish to acknowledge the help and support of Rita Peys and Annie De Wit, K VIV staff.

Conference chairman
Rudy Denys

The Pipeline Technology Conference 1995 was organized by : **The Technological Institute of the Royal Flemish Society of Engineers (TI-K VIV)**

The K VIV is the professional organization of the academically trained Flemish engineers. It represents more than 11.000 members.
In 1940 the Society founded the Technological Institute, with the aim of disseminating information on scientific and technological development by means of seminars, lectures, courses, congresses, conferences.

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CONTENTS

VOLUME I

WELDING CONSUMABLES

PIGGING

PLASTICS PIPES

PIPELINE INSTALLATION

PIPELINE WELDING

CONVENTIONAL PIPELINE STEELS

PLASTIC PIPES

WELD METAL MATCHING

WELDING ON PIPELINES

CORROSION

LATE PAPERS

Pipeline Technology, Volume I
R. Denys (Editor)

Pipelines in the 1990's... And Beyond

E. Glynn Jones, Bechtel International, Inc.

Second International Conference on Pipeline Technology
Antwerp, Sept. 11-14, 1995

Introduction

The near-future of the pipeline industry promises to present the engineer and project developer with a broad spectrum of new challenges and opportunities. The trend to international cooperation to efficiently develop the world's energy reserves, and to deliver them cost-effectively to end-users accelerates. The net effect is to improve the standard of living of the World's peoples. More and more people around the World are beginning to take for granted readily available, inexpensive, and reliable access to energy to improve their daily lives.

Pipelines to transport oil, oil products, and gas from where they are produced to where they are consumed continue to evolve as the safest, most economically efficient, and least environmentally-disruptive method of transport, leading to:

- synergistic international cooperation in the development of pipeline projects; and
- application of emerging cost effective and environmentally-friendly technologies to the design, construction, and operation of oil and gas pipelines, improving their safety and reliability.

Pipelines to transport of other commodities such as coal, metal ores and minerals by slurry are also continuing to evolve as a cost-effective and least environmentally-disruptive method.

The development and implementation of contemporary major pipeline systems presents many challenges and opportunities, such as:

- An integrated systems approach to optimize cost-effective and innovative approaches to system configuration, financing, contracting strategy, materials sourcing, and operating basis and plan;
- Pushing technology further into leading-edge applications, e.g.,new materials, new environments, such as deeper offshore water, and transcontinental scope projects applying "cutting edge" and emerging technologies, new materials (grade X-80 line pipe), sophisticated computer-based supervisory and control systems, advanced communications systems employing fiber-optic cables or satellites, turbines with lower nitrogen oxide emissions, directionally drilled river crossings, and advanced laybarges;

- Adherence to high standards to protect the environment is increasingly required by local governments and international funding agencies, including The World Bank and EBRD and strong design emphasis on system safety;

- Development of innovative approaches to project financing such as commercial credit, barter, and joint venturing;

A creative, systems approach to these challenges is often the key to the project moving ahead. This usually encompasses collaboration between international engineering and construction companies, equipment and materials suppliers, in-country engineers and constructors, and financial institutions.

Profile of an International Pipeline Engineering and Construction Company

Starting in the 1930's, Bechtel performed design and construction of major pipeline projects in South America. In the 1940's, Bechtel was involved with design and construction of TAPLine, the Trans Arabian Oil Export Pipeline system terminating on the Mediterranean Sea. In the 1950's, the scope of Bechtel's overseas work expanded to Europe, and in the 1960's, to North Africa.

The Trans-Mountain pipeline in Canada was one of the first mountain pipelines constructed and pioneered the use of slack flow regimes in steep downhill slopes.

The Trans-Alpine and the PetróPeru and Oxy Colombia Trans-Andes pipeline required innovative construction techniques to lay the pipeline in the extreme mountainous terrain.

The Trans-Alaska crude oil pipeline was one of the first Arctic pipelines constructed and had the further complexity of transporting hot crude through permafrost areas.

In the slurry pipeline area, the Black Mesa coal slurry pipeline was the first major commercial coal slurry pipeline and is experiencing 20 years of successful operation.

Today's environmental challenges were addressed on a daily basis during the recent construction of the Canada-to-California gas pipeline.

Technological Change

Over the years, the pipeline industry has been a leader in technological innovation, and this continues:

- <u>New and better materials</u> continue to be developed and adopted by the pipeline industry. For instance, greater use of higher yield strength line pipe, such as grade X-80 pipe, as well as bi-metallic line pipe for transmission of high pressure corrosive fluids. Code committees in the United States are now approving use of a fiber-glass wrap to repair certain kinds of corrosion damage.

- More powerful and less expensive computers, combined with better scientific understanding of the behavior of high pressure fluids, have allowed better simulation of complex and transient hydraulic conditions in pipelines. It is now possible to model pipelines carrying multi-phase fluids, dense phase fluids, multiple products, as well as complex pipeline networks.

- SCADA systems, the computerized "system control and data acquisition" systems that typically control modern pipeline systems, can improve the reliability and sensitivity of a leak detection systems. In addition, SCADA systems prove invaluable in coordinating pipeline controls where multiple products are carried within the pipeline simultaneously. Liquid pipeline systems, for instance, designed to transport "batches" of a number of liquid fuels, can be complex to control efficiently. Computerized control allows safer and more efficient operation of such pipeline systems.

- New, dedicated communication systems for transmission of pipeline data to the SCADA system increasingly utilize either dedicated fiber optic cables buried along pipeline rights-of-way or dedicated satellite-relay systems.

- Low emissions, high efficiency gas turbines result in lower environmental impact. On the recently-completed Canada to California gas pipeline, the world's first high-efficiency aero-derivative 'dry low emissions' Rolls Royce RB 211 turbine was employed. Validation testing demonstrated that the NOx level in the exhaust gas was reduced to under 25 ppm, with CO barely measurable.

- Variable frequency drivers provide greater flexibility in pipeline pump and compressor operations.

- Remote sensing and imaging data technology can identify the most cost-effective pipeline routes. When digitized, such imaging data can be combined with position data (e.g., latitude and longitude), as well as a variety of other site-specific data along the pipeline right-of-way, in a geographical information system (GIS). The GIS can be used to produce the pipeline alignment sheets for pipeline construction and "as-built" drawings. Land ownership and operational data can also be added to a GIS. This can provide an important asset to a pipeline operating organization.

- New and evolving ditching technologies are used for excavation in hard soils and even bedrock, without use of explosives. For instance, on Bechtel's ongoing gas pipeline project in Algeria (part of the Algeria to Spain pipeline system) Bechtel has collaborated with the U.S. firm Jetco to develop a chain-type ditching machine approximately twice as large as preceding models. These ditching machines are performing well in limestones with compressive strengths in excess of 15,000 psi (over 1,000 kg/ cm^2).

- "Trenchless" pipeline installation methods, such as directional drilling and micro-tunneling, are currently employed at water crossings where other methods are unsatisfactory. A virtue of this technology is that the ground surface above the pipeline is not disturbed. A river crossing can be installed at a far greater depth below the bed of a river by directional drilling than traditional cut and cover methods, while avoiding any surface disturbance within the active floodplain of the river.

- Growing use of "smart pigging" technologies enable detection of material and construction defects in an installed pipeline, or deterioration in an operating pipeline resulting from internal or external corrosion. Increasingly baseline smart pig surveys are run as part of the commissioning of a just-completed pipeline. As data storage and computing technologies continue their rapid advancement, use of pipeline inspection technologies will become more routine.

- New technologies for detection of leaks along pipelines, of natural gas, oil, and oil-products. Such technologies are increasingly capable of not only telling if a leak is occurring, but also the rate of leakage, and even where the leak has occurred. Some methods, currently only economically feasible over relatively small distances, permit detection of leaks at very small flowrates.

- Offshore pipelines are now constructed of larger diameter at higher pressure, over longer distances, and in deeper waters.

Environmental Impacts

It is interesting to observe the effects of growing "environmentalism" on the pipeline industry. It is apparent that concern about a degrading environment is stimulating the construction of new pipeline systems. This is based on the realization that pipelines are more efficient, safer and less environmentally disruptive than other methods of bulk fluid transport. For instance, comparing pipelines with rail or road transport of bulk fluid, one typically sees:

- dramatic reductions in fuel use per ton-mile of commodity transported;

- fewer numbers of accidental releases and lesser volumes of product accidentally released to the environment;

- minimal environmental impact from pipeline operations.

Worldwide concern with environmental protection is placing greater constraints on all large construction projects, such as those required to construct extensive pipeline systems. Since pipelines are commonly routed through remote and undeveloped areas, additional constraints may be imposed to protect the wilderness. Often, the environmental conditions that the pipeline project developer must protect are not fully known until surveys are conducted along a proposed pipeline route, in advance of pipeline construction.

The most significant impacts that environmental constraints normally produce on pipeline projects occur during pipeline construction; after the pipeline is placed in operation, existing international codes and standards governing safe pipeline operation are typically considered sufficient to adequately protect the environment.

The Canada to California gas pipeline, completed in 1993, provides examples of current environmental constraints. It is noted that this 42-inch pipeline passes through wilderness over much of its alignment, through the states of Idaho, Washington, Oregon, and California and it is routed a nominal 30 feet away from an existing 36-inch gas pipeline, owned by the same operating company, that was placed into operation in 1961. Thus, construction of the 1993 pipeline did not require clearing of a new pipeline right-of-way through wilderness areas, but only the re-use of an existing right-of-way.

Bechtel was the engineering, procurement and construction contractor on both projects, and in a unique position to compare the environmental and regulatory climate prevailing for major pipeline construction projects in the Western United States thirty years ago, with that existing today. Additional or extended requirements for the 1993 pipeline construction project were numerous as described below.

Multiple Federal, State and local government jurisdictions, all required submissions and approvals of permits to construct the pipeline system. In fact, acquisition of over 1800 major permits took twice as long as the time required to actually construct the pipeline. Areas requiring analysis of potential impacts from the pipeline project for permits included:

- geology and soils
- hydrology and water quality
- land use
- vegetation and wildlife
- fisheries
- socioeconomics of peoples effected by pipeline
- air quality and noise
- transportation
- public safety
- visual resources
- cultural resources and paleontology.

Special safeguards for rare and endangered species proved to be an important consideration during construction. For instance, if a raptor was found to be nesting within one-half mile of the pipeline right-of-way, pipeline construction was discontinued and moved ahead to another area. This, of course, necessitated returning to the "skipped" portion of pipeline construction at a later date, when the young birds had hatched, fledged, and were not returning to their nests. Some rare species were not discovered along the pipeline right of way until wildlife surveys were conducted. This became more critical since surveys of wildlife living in the vicinity of the pipeline right-of-way, were scheduled to occur not more than 60 days in advance of pipeline construction. Surveys of plant and insect life in advance of pipeline construction were also conducted to identify plants and insects that could be adversely effected by pipeline construction.

Ephemeral (seasonal) pools of water develop along the pipeline right of way in California in topographic depressions. These "vernal" pools have been found to support rare species of plants and animals. Consequently, extremely complex and expensive measures were required to either avoid such areas, or to restore them after the pipeline was constructed.

Archeological and paleontological surveys required in advance of pipeline construction, for all construction-related areas along the pipeline, with a requirement for multiple levels of approval in advance of construction activities. In addition, Native American "monitors" were required to continuously observe construction activities, with the authority to stop construction.

In comparison, the environmental constraints imposed on the parallel, 1961 pipeline were both qualitatively and quantitatively different, and the expense to the client (and, ultimately, the consumer) considerably less than those incurred for the 1993 pipeline.

Clearly, society must consider the cost/benefit of the measures it requires to achieve environmental protection. Pipelines built to current modern international standards for quality and protection of the environment typically provide great benefit at minimal environmental impact.

Safety Considerations

Particularly for highly flammable liquids such as LPG or gasoline, transport through pipelines offer many advantages in safety and compared to truck or rail transport. Pipelines built to today's engineering and quality standards are far less subject to accidental release resulting from accidents, and do not burden the road or rail infrastructure with high levels of traffic. Safety was an important consideration leading to India's Kandla-Bhatinda Pipeline System. This system is designed to carry liquid fuels from the Gulf of Kutch to New Delhi and the State of Punjab and will provide the advantage of slowing the increase in traffic of fuel tankers on India's highways.

Pipeline safety is best demonstrated by statistics. The following pipeline safety data has been taken from a paper entitled "Ensuring the Safety of Older Pipelines" given by P. Hopkins of British Gas, at the International Pipeline and Offshore Contractors Association, 28th Convention, Acapulco, Mexico, September, 1994:

> *"Different organizations report pipeline 'failure' according to varying definitions. For example, in Western Europe, gas and oil pipeline failures are described as any product loss incident. In the United States, a 'failure' with a gas transmission pipeline is a gas loss incident that also involves a fatality or injury, or damages in excess of $50,000. Therefore, Western Europeans report more 'failures' than do Americans, and the data is believed to be more relevant to place this issue in context.*

Based on nearly 20,000 km of onshore oil pipelines in Western Europe, and nearly 93,000 km of onshore gas pipelines, over a 22 year period, one can expect an average rate of 0.6 to 0.8 loss-of product incidents per year per 1000 kms of pipeline (for gas and oil pipelines, respectively). Causes, in approximate order of decreasing significance, are:

Cause of Incident	*Gas Pipelines*	*Oil Pipelines*
External Interference (which includes damage by "dig-ins")	*0.3*	*0.25*
Both Internal and External Corrosion	*0.1*	*0.26*
Construction/Material Defects	*0.1*	*0.2*
Ground movement (including flooding)	*0.05*	*0.04*
Other Causes (which includes operational error)	*0.05*	*0.05*
Total	*0.6*	*0.8*

Based on the statistics drawn on in the preceding table, oil and gas pipelines can be expected to have the following frequency of incidents/failures:

Any incident requiring a repair = *4.0 / 1000 km /year*

Loss of product event = *0.6-0.8 / 1000 km / year*

Failures with associated casualties or high damage costs = *0.16 / 1000 km / year"*

Compared with overland transportation alternatives, such as road and rail transport, this rate of measurable losses is far lower, both on a distance basis and on a distance/volume basis.

Opportunities From Global Change

Global changes are bringing new opportunities for the pipeline industry:

- The opening of the Former Soviet Union ('FSU') and the emergence of rapidly expanding economies in Asia and Latin America
- Trends toward privatization and deregulation
- Use of clean-burning fuels, such as natural gas
- Decreasing reliance on building new nuclear power plants and greater interest in increasing LNG imports for power generation.
- Advancement of the international petroleum industry into entirely new and remote producing areas.

Pipeline Construction Forecast - 1995 and Beyond

Substantial increases in the rate of construction of new pipeline systems around the World are anticipated over the next few years. Over the period 1989 through 1994, the average number of miles of new pipeline planned around the World has been 133,000 miles (214,000 kilometers) per year according to the January 1994 issue of Pipeline Digest.

Although Worldwide totals of new pipelines planned fell substantially between 1990 and 1991, they have slowly recovered from 1991 through 1994. Overall, there was a net positive trend in pipeline mileage of approximately 2% per year over the 1989 through 1994 period.

It is interesting to note that, in 1994, approximately 75% of new pipelines planned were for natural gas. In addition, in 1994, approximately 40% of new pipelines planned were for the Asia/Pacific/Australia region. These trends are expected to continue over at least the next five years. The fastest-growing economies of the World will probably continue to be found in the Asia/Pacific/Australia region, bringing a continuation in the trend toward construction of new pipelines.

In particular, expansion of the economies of India and China could lead to several major new pipeline projects, such as:

- New products pipelines, in addition to the ongoing Indian pipeline system connecting the Gulf of Kutch through Rajistan with Punjab (Kandla-Bhatinda Products Pipeline).
- New slurry pipelines to transport commodity minerals (e.g., iron ore, coal) from mines in the interior to coastal ports, for export.
- New petroleum pipelines, such as an oil pipeline from the Tarim Oilfield in China to the coast.

The National Pipeline Research Society of Japan is planning a major network of gas pipelines to interconnect all of Asia's gas resources with the markets and linking all of the Asian economical zones. This ambitious project is designed to take us into the 21st Century.

The much discussed Arabian Gulf to India gas pipeline system will have significant challenges whether it is constructed on land or offshore. On land, it is faced with the political uncertainties of traversing several countries with divergent political policies. Offshore it is faced with water depths in excess of 1,000 meters which are unreachable with current technology.